

Dichotic Word Recognition in Young Adults with Simulated Hearing Loss

A Senior Honors Thesis

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by

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ABSTRACT

The purpose of the present study was to examine dichotic speech recognition in young adults with simulated hearing loss to more appropriately compare performance to older adults. Twelve young adults with normal hearing participated. Dichotic word recognition (DWR) performance was measured under unprocessed and processed conditions. In order to simulate hearing loss, the stimuli were filtered using the Moore and Glasberg (1993) hearing loss model and a reference audiogram (re: Roup et al., 2006). For each condition, DWR was measured using free-recall, directed-right and directed-left response paradigms. Results indicated two main findings: (1) a significant reduction in overall recognition performance from the unprocessed to processed condition, and (2) small and consistent changes in the magnitude of the ear advantage were observed between response paradigms. Results from the processed condition were then compared to DWR in noise (Moller, 2007) and older adult DWR (Roup et al., 2006). Processed DWR performance was better than DWR in noise and the REAs were similar. Processed DWR performance was also better than DWR in older adults, although the REA was significantly smaller than the REA exhibited by older adults. The significant differences in REAs between young (small REA) and older adults (large REA) suggests different auditory processing abilities, particularly an age-related decline in auditory processing for the older adults.

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Chapter 1

INTRODUCTION AND LITERATURE REVIEW

For normal hearing individuals, speech understanding typically comes with little to no effort. In noise, however, this reasonably simple task becomes more difficult. In most cases, hearing in a competitive listening environment is easy for young adults. In these situations, young adults' ability to recognize and understand speech is relatively unaffected. Older adults, on the other hand, experience greater difficulty with speech understanding in noisy environments. This difficulty in speech understanding is due to hearing loss that generally accompanies the aging process.

One way to test speech understanding is to present words dichotically. In dichotic listening tasks, the examiner simultaneously presents two different speech signals to each ear of the subject via headphones. The listener is then asked to recall one or both of the competing stimuli. Research has shown that subjects typically recall a greater number of the stimuli presented to the right ear as opposed to the left ear. This difference in the recollection of stimuli between the right and left ears has been termed a right ear advantage, or REA (Kimura, 1967).

Language Lateralization and Dichotic Listening:

Knowledge of the auditory pathways and interhemispheric transfer can help to explain this right ear advantage. When traveling to the brain, information from the ears travels both ipsilaterally to the same side of the head, and contralaterally to the opposite side of the head. According to electrophysiological studies, direct auditory pathways to

the ipsilateral hemisphere are not as strong as contralateral pathways, which cross to the opposite hemisphere (Kimura, 1967). Although each hemisphere has connections with the auditory pathways from both ears, the contralateral pathways are more efficient than the ipsilateral (Kimura, 1967). Behavioral research suggests that we rely on information from the contralateral pathways, while suppressing information from the ipsilateral pathways. With that, information from the right ear travels most effectively contralaterally to the left hemisphere, where language processing typically occurs. The signal in the left ear travels to the right hemisphere and must then be transferred via the corpus callosum to the left hemisphere for processing. The interhemispheric transfer of signals presented to the left ear, which is not necessary for signals presented to the right ear, results in fewer stimuli being correctly processed when presented to the left ear in dichotic listening conditions.

Research has also shown that older adults perform more poorly on dichotic listening tasks, in general, and show greater right ear advantages when compared with younger adults (Roup, Wiley, & Wilson, 2006). The poorer overall performance in older adults is expected and can easily be explained by the fact that older adults experience peripheral (inner ear) hearing loss as part of the normal aging process. The greater right ear advantage, or left ear disadvantage, is not as easily explained. Some investigators have suggested that the effect found in the elderly may be due in part to an additional loss of energy during interhemispheric transfer that occurs with aging of the central auditory pathways (Jerger, Alford, Lew, Rivera, & Chmiel, 1995). In other words, Jerger and his colleagues suggested that the difference might be due to a central effect in addition to the peripheral hearing loss that occurs with aging.

Stimuli:

Various options exist for stimuli that can be used in dichotic speech recognition tests. Digits, words, sentences, and consonant vowels are all types of speech stimuli. When using digits during dichotic listening, the participant has a slight advantage. Digits are a closed stimulus set, meaning there are a limited number of choices from which the participant can guess. The digits are highly recognizable, as subjects are extremely familiar with these words. In many cases, monosyllabic words are favored over digits, sentences, and consonant-vowel syllables for four important reasons. First, the use of syntactical cues is minimized when using words. Second, monosyllabic words are standardized and commercially available for widespread use. Third, there exists a large database for listeners with normal and impaired hearing. Lastly, monosyllabic words comprise an open stimulus set, unlike digits. This means there are almost endless amount of monosyllabic words that may be used, which limits the participant's ability to guess the correct answer. It is for the previous reasons that Roup, Wiley, and Wilson (2006) used monosyllabic words in their dichotic research. The remaining stimulus options are less desirable when performing dichotic listening tests. Too many contextual clues are available when listening to sentences, giving the participant an advantage in performance. In regard to consonant vowel testing, many researchers believe this task is too difficult.

Handedness and Dichotic Listening:

Handedness is related to the way in which humans lateralize information in their brains. For most people, language is processed in the left hemisphere. It is the case

that most right-handed people process language information in their left hemispheres, so it may be assumed that left-handed people process language information in the right hemisphere. However, similar to right-handers, left-handed people are still more likely to process language in their left hemisphere, although not as many left-handers as right-handers exhibit this trend.

Research involving dichotic performance of right- and left-handed listeners by Wilson and Leigh (1996) indicated a difference in performance levels on the task. They collected data from 24 right-handed listeners and 24 left-handed listeners using the dichotic consonant-vowel materials. According to the results, both right- and left-handed individuals exhibited a right ear advantage. However, left-handed subjects were more variable in their performance when compared to the right-handed subjects. Right-handed subjects identified 72.8% of the stimuli presented to the right ear and 56.5% of the stimuli presented to the left ear, resulting in a 16.3% right-ear advantage. On the other hand, left-handed subjects identified 62.9% of the stimuli presented the right ear and 61.1% of stimuli presented to the left ear, resulting in only a 1.8% right-ear advantage. To guarantee less variability and a higher degree of reliability in the testing measures, handedness is controlled for in dichotic listening research.

Gender and Dichotic Listening:

Research shows that the gender of the participant does contribute to the performance levels for dichotic listening situations. According to Jerger, Chmiel, Allen, and Wilson (1994), as age increases, females show a decrease in performance in the right ear when compared to males. On the other hand, females show greater

performance than males in the left ear. As a result, older males exhibit a larger right ear advantage than older females due to their better right ear performance and worse left ear performance.

Piazza (1980) studied the influence of gender on hemispheric processing in two groups of young adults. Within the study were 8 males and 8 females who participated in dichotic listening tasks, using both verbal and nonverbal stimuli. Research supported that gender of the subject played a role in the lateralization of information to the hemispheres. More specifically, females excelled when processing nonverbal speech stimuli, while males excelled with speech-stimuli. The difference in performance between male and female subjects, however, was small (5.7% vs. 3.1%, respectively).

The gender of the subject is an important variable throughout dichotic research. Bellis and Wilber (2001) suggest that there are gender interactions with aging that affect interhemispheric transfer during auditory stimulation for subjects who are middle-aged. For early and late adulthood, however, Bellis and Wilber advocate that the gender effects on the auditory evaluation of interhemispheric transfer are small and clinically insignificant.

Age Effects on the Ear Advantage:

Many studies have shown that older adults have a much greater right ear advantage than young adults. This right ear advantage is most likely due to an age-related processing disorder found in older adults, and not due to the peripheral hearing loss.

Bellis and Wilber (2001) researched the right ear advantage (REA) found in dichotic listening tasks in several age groups. Participants were placed in four groups based on age; ages 20-25, ages 35-40, ages 55-60, and ages 70-75. In their study, Bellis and Wilber found that although an REA was found in all groups, the oldest age group (ages 70-75) exhibited a larger REA than the youngest age group (ages 20-25)—6% as compared to 2%. Because many older adults possess age-related peripheral hearing loss, it is no surprise that the overall performance of older adults is worse than younger adults. Because the hearing loss is symmetrical bilaterally, only a small REA would be expected due to the use contralateral pathways during dichotic listening tasks. However, the REA in the older adults was significant in size which suggests that it is not the peripheral hearing loss causing a large REA, but rather, a central auditory processing disorder related to age.

Interhemispheric transfer is affected by aging in that as adults get older, the corpus callosum suffers many changes. The corpus callosum is responsible for connecting the two hemispheres and acting as a communication line for the brain. Jerger, Alford, Lew, Rivera and Chmiel (1995) studied the idea that age may affect the communication between hemispheres of the brain. Decreased integrity of the corpus callosum would result in a shortcoming in the transfer of information between hemispheres and would therefore be the cause of an auditory processing disorder in older adults.

Moller (2007):

In an attempt to differentiate the peripheral and central components of the dichotic listening task results in the elderly, Moller (2007) completed a study involving dichotic word recognition in young adults in noise. By introducing speech spectrum noise to the dichotic word lists, she effectively lowered the performance levels of the normal hearing participants. Moller then compared the results of young adults with simulated hearing loss to the results obtained by Roup et al. (2006) from elderly listeners. She postulated that if the recall performance from the young adults in noise matched the performance results obtained from elderly listeners then the results from the elderly listeners could be explained by peripheral hearing loss alone. On the other hand, if the results from younger listeners with simulated hearing loss did not match the results from the elderly listeners (i.e., did not show the large REA), a central aging component could be assumed.

The young adults in Moller's (2007) study showed worse performance on the dichotic word recognition task in the presence of noise when compared to performance in the quiet condition. The study also showed smaller REAs in the young adults than Roup et al. (2006) noted in their study of elderly listeners. Thus, Moller's data support the idea that the large REA seen in elderly adults is not due to peripheral hearing loss alone.

Moller introduced speech spectrum noise to the dichotic words to lower performance levels of the listeners. One could argue that this is not an optimal representation of hearing loss as it does not simulate all aspects of peripheral hearing loss. Notably, it doesn't directly simulate the broadening of the auditory filters that is

known to occur with the loss of the outer hair cells in the inner ears of elderly listeners. The addition of noise is not frequency specific, unlike the age related sensorineural hearing loss that is so common in older adults, which more severely affects the higher frequencies of speech rather than the lower frequencies.

Clinical Implications:

Research involving dichotic word recognition performance has clinical implications. Today's standard of practice is to fit binaural hearing aids (hearing aids on both ears) to elderly individuals with hearing loss. But, if it can be demonstrated that some older adults have an auditory processing disorder resulting in a larger than expected right ear advantage, monaural amplification rather than binaural amplification might be more appropriate (Carter, Noe, & Wilson 2001). Monaural amplification could be advantageous for these individuals because it would allow them to process information through their "stronger" right ear without potentially distracting information from their left ear. Carter, Noe and Wilson tested word-recognition performance using both monaural and binaural amplification in older adults with bilateral hearing loss. Results of this testing revealed better performance with monaural right-ear amplification due to left-ear processing deficits. In patients experiencing an auditory processing disorder, monaural amplification may be the best option, despite a binaural peripheral hearing loss.

Present Study:

The proposed study will use a different form of hearing loss simulation, which will be referred to as Moore & Glasberg's hearing loss simulation model. The advantage to this hearing loss simulation method is that it simulates hearing loss by reducing the audibility of the signal (to create the effect of poorer than normal thresholds) and it smears the spectral content of the speech (to create the effect of broadened auditory filters) (Moore & Glasberg, 1993).

The proposed study seeks to answer the same question asked by Moller—is the large REA seen in elderly listeners due to peripheral hearing loss alone or does the aging of the central components of the auditory system play a role? Specifically, this study will compare data collected using the Moore & Glasberg hearing loss simulation model with data previously collected by Moller (2007) and Roup et al. (2006) to answer the following questions:

1. How do the REAs of young adults with normal hearing compare to the REAs of the same young adults with hearing loss simulated using the Moore & Glasberg Model?
2. How do the REAs of the young adults with simulated hearing loss compare to those of the older adults with hearing loss? Does the REA in young adults remain small, or is the REA increased, similar to the increase seen in older adults?
3. How does the difference in mode of hearing loss simulation (noise vs. Moore & Glasberg simulation) affect the dichotic word recognition scores and REAs?

Chapter 2

METHODS

Subjects

Twelve participants were included in the present study, each of whom was recruited from The Ohio State University student population and surrounding Columbus, Ohio community. Of the 12 subjects involved with the study, 5 were male and 7 were female. The participants ranged in age from 19 to 23 years old, and all must be right-handed. To ensure right-hand dominance, each participant completed a simple 10-item questionnaire, known as the Edinburgh Handedness Inventory (Oldfield, 1971; see Appendix A). This test measures the right-handedness of a person quantitatively. A resulting score of ≤ 20 guaranteed that the individual was right-handed. Those who were left-handed or not dominantly right-handed were excluded from the study to reduce variability in the dichotic listening task.

Participants were required to meet several inclusion criteria in order to qualify for the present study. All participants possessed tympanometry within normal limits and normal otoscopy (no sign of structural abnormalities, a clear external ear canal, and a healthy tympanic membrane). A standard audiometric assessment was performed to verify normal hearing sensitivity bilaterally. Normal hearing is defined by pure tone thresholds ≤ 20 dB HL at 250 to 8000 Hz. Additionally, bone conduction thresholds were within 10 dB of air conduction thresholds, signifying no air-bone gap was present. Lastly, payment in the amount of \$10 per hour was awarded to each participant in recognition of the time contributed to the study.

Materials

Two hundred monosyllabic words from the Northwestern University Auditory Test No. 6 (NU-6) paired dichotically were used to measure dichotic speech recognition (see Roup et al., 2006 for details). In order to simulate hearing loss (i.e., the processed condition), the word pairs were filtered electronically using Moore and Glasberg's (1993) hearing loss simulation model. This model simulates hearing loss by reducing the intensity of the signal (to create the effect of poorer than normal thresholds) and it smears the spectral content of the speech (to create the effect of broadened auditory filters) (Moore & Glasberg, 1993). The model reduces the audibility of the signal based on audiometric threshold information that is specified prior to processing. Specifically, mean hearing thresholds from the 70-79 year old age group from the Beaver Dam, WI prevalence of hearing loss study were used (Cruickshanks et al., 1998). The same mean hearing thresholds were used as criteria for the older adult subjects from Roup et al. (2006). Therefore, the model simulated the same degree of hearing loss as that of the older adult comparison group.

Pilot data with the processed stimuli (reduced audibility and spectral smearing) resulted in extremely poor dichotic word recognition performance (i.e., floor effects of <30% recognition). Pilot data with the stimuli processed without the spectral smearing was considerably better and did not result in floor effects. The simulation of hearing loss, therefore, used only the dynamic range reduction portion of the simulation model.

Procedures

To familiarize participants with the dichotic listening task, sample items were presented to the subject prior to the actual test. Each practice consisted of a 10-item dichotic word set, and responses were not recorded.

All participants completed a total of six dichotic word recognition tests, using standardized lists of 50 dichotic word pairs. Three response paradigms (or patterns) were used in this study. First, the free-recall response format was used. In this situation, the subject was instructed to recall the stimuli from both ears, in any order. Next, the directed-attention right response format was utilized. Here, the subject was instructed to recall the stimuli from the right ear first and then the stimuli from the left ear. Lastly, the directed-attention left response format was used. The subject was instructed to recall the stimuli from the left ear first, followed by the stimuli heard in the right ear.

The previous three response paradigms were each tested using two experimental conditions, unprocessed and processed. When the stimuli were unprocessed, the participants were performing the dichotic listening task with normal hearing. When processed, the participants were presented filtered dichotic lists to simulate hearing loss.

To familiarize the participants with the dichotic listening task, unprocessed stimuli lists were presented first, followed by processed stimuli lists. All dichotic word lists were counter-balanced across the 12 participants to minimize order effects.

Chapter 3

RESULTS

Unprocessed vs. Processed Dichotic Word Recognition

Table 1 presents mean dichotic word recognition data for both right and left ears across experimental conditions and response paradigms. Figure 1 depicts the ear advantage (in percent) for each experimental condition (unprocessed and processed) across each of the three response paradigms (free recall, directed attention right, and directed attention left). Ear advantage (in percent) is represented on the abscissa and response condition is represented on the ordinate. As can be seen in Figure 1, differences in ear advantage were found between unprocessed and processed conditions for all response paradigms. In the free recall response paradigm, processing resulted in an unexpected finding. Typically, a small right ear advantage would be exhibited in the free recall situation. A 7.50% REA was found for the free recall response paradigm in the unprocessed condition; however, no advantage was found in the processed condition. In the directed right response paradigm, a 7.00% REA was found in the unprocessed condition and an 11.20% REA was found in the processed condition. In the directed left response paradigm, a 4.20% LEA was found in the unprocessed condition and a 3.30% LEA was found in the processed condition.

Prior to statistical analysis, the dichotic word recognition percentage scores were converted to rationalized arcsine units (Studebaker, 1985) to eliminate the error associated with percentage data. Paired samples *t*-tests were used to determine if significant differences were present between right and left ears in the *unprocessed*

	<u>Right Ear</u> %	<u>Left Ear</u> %	<u>Overall</u> %
<i>Unprocessed</i>			
<u>Free Recall</u>			
Mean	84.5	77.0	80.8
SD	7.5	9.1	8.3
<u>Directed Right</u>			
Mean	89.3	82.3	85.8
SD	6.5	11.7	9.1
<u>Directed Left</u>			
Mean	85.0	89.2	87.1
SD	5.8	5.4	5.6
<i>Processed</i>			
<u>Free Recall</u>			
Mean	64.7	65.2	65.0
SD	10.7	10.7	10.7
<u>Directed Right</u>			
Mean	73.3	62.2	67.8
SD	7.8	12.4	10.1
<u>Directed Left</u>			
Mean	68.2	71.5	70.0
SD	11.2	8.6	9.9

Table 1. Means and standard deviations of dichotic word recognition performance from the free recall, directed right, and directed left response paradigms for right and left ears, and combined across ears (overall) in both conditions (unprocessed and processed).

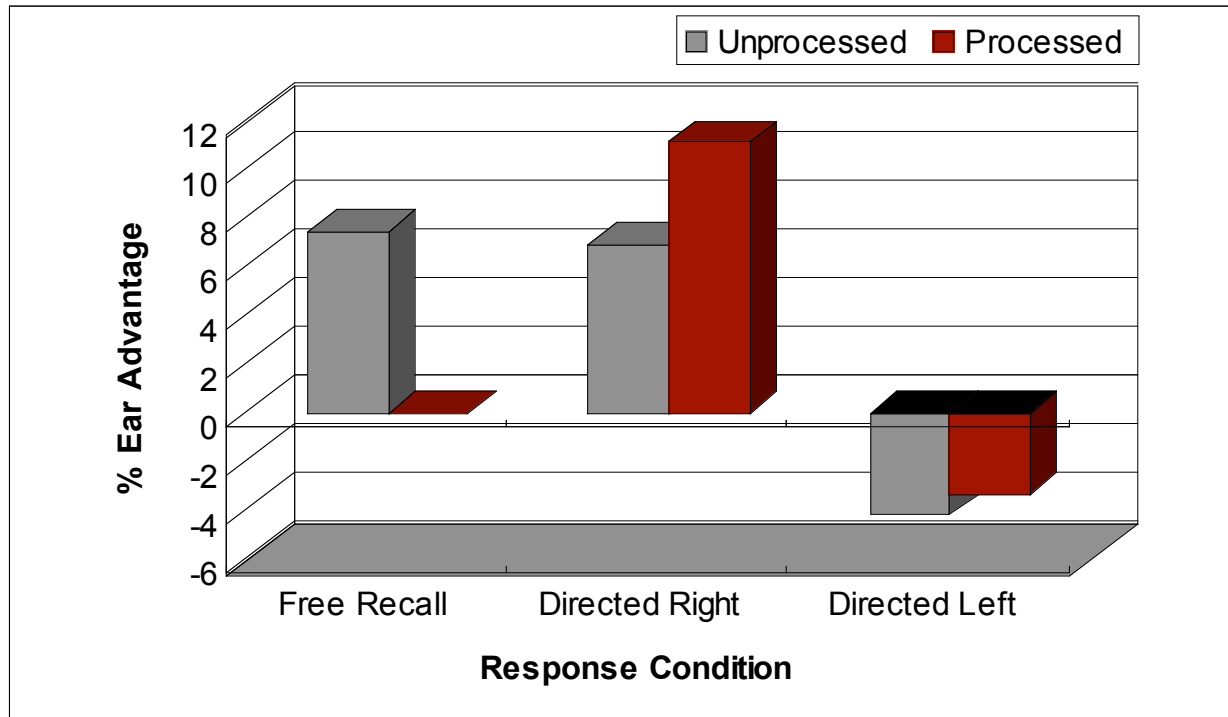


Figure 1. Mean ear advantages (in percent) for unprocessed and processed conditions across the three response paradigms: free recall, directed right and directed left.

condition. Results revealed significant differences between ears for all response paradigms: free recall ($t_{11} = 3.85$, $p < .05$), directed right ($t_{11} = 2.21$, $p < .05$), and directed left ($t_{11} = -2.52$, $p < .05$). Specifically, performance of the right ear was superior to the left ear in both the free recall and directed right response paradigms, whereas performance of the left ear was superior to the right ear in the directed left response paradigm. A one-way repeated measures analysis of variance (ANOVA) was conducted in order to determine if significant differences were present between response paradigms in the unprocessed condition. Results revealed a significant main effect of *response paradigm* ($F_{2, 22} = 8.26$; $p < .05$). Post-hoc Bonferroni *t*-tests revealed significant differences between free recall and directed left ($t_{11} = 4.64$, $p = .001$) and directed right and directed left ($t_{11} = 2.94$, $p = .013$). The difference in performance between free recall and directed right was not significant ($t_{11} = -0.41$, $p = 0.69$).

Paired samples *t*-tests were used to determine if significant differences were present between right and left ears in the *processed condition*. Results revealed a significant difference between ears for the directed right response paradigm only ($t_{11} = 3.23$, $p < .05$). Results were not significantly different between ears for free recall ($t_{11} = -0.39$, $p > .05$) or directed left ($t_{11} = -0.87$, $p > .05$) response paradigms. A one-way repeated measures ANOVA was conducted in order to determine if significant differences were present between response paradigms in the processed condition. Results revealed a significant main effect of *response paradigm* ($F_{2, 22} = 6.17$; $p < .05$). Post-hoc Bonferroni *t*-tests revealed a significant difference between free recall and directed right response paradigms ($t_{11} = -4.14$, $p = .002$). The difference in performance

between free recall and directed left ($t_{11} = 0.39$, $p = .71$) was not significant, nor was the difference in performance between directed right and directed left ($t_{11} = 2.62$, $p = .02$).

In order to determine if dichotic word recognition performance differed between unprocessed and processed conditions, a two-way repeated measures ANOVA was conducted with *processing* and *response condition* as within subjects factors. Results revealed a significant main effect of *processing* ($F_{2, 23} = 287.5$; $p < .05$). Specifically, dichotic word recognition performance was poorer as a result of the simulated hearing loss processing than in the unprocessed condition. Results also revealed a significant main effect of *response condition* ($F_{2, 23} = 7.7$; $p < .05$). Post-hoc comparisons (with Bonferroni correction) revealed significant differences in performance across response conditions as a function of processing. Specifically, performance for unprocessed free recall was significantly better than processed free recall ($t_{23} = 7.3$ $p < .017$). Performance for unprocessed directed right was significantly better than processed directed right ($t_{23} = 8.8$; $p < .017$). Also, performance for unprocessed directed left was significantly better than processed directed left ($t_{23} = 9.4$; $p < .017$).

Comparisons with Young Adults in Noise and Older Adults

The introduction of simulated hearing loss (present study) and noise (Moller, 2007) was intended to equate overall performance between young and older adults, allowing for direct comparisons of the right ear advantage. As seen in Figure 2, the REAs exhibited by young adults in the present study (processed) and from Moller (2007; noise) remained small, similar to REAs exhibited in quiet conditions. The mean REA exhibited by older adults (Roup et al., 2006), however, is significantly larger than

young adults, despite similar levels of overall recognition performance. Table 1 shows the means and standard deviations for dichotic word recognition (in percent correct) for both ears, as well as the right and left ear combined (overall). Data from the free recall paradigm are shown for both conditions (unprocessed and processed). For comparison, data from the young adults in noise (Moller, 2007) and the older adults (Roup et al., 2006) are also shown in Table 2. As can be seen in Table 2, the mean performance of the right and left ears in the unprocessed condition was 84.40% and 77.00%, respectively. In the processed condition, however, mean performance of the right and left ears was 64.70% and 65.20%, respectively. The mean performance of the young adults with simulated hearing loss was reduced in comparison to the unprocessed data, but was not reduced to the performance level of the young adults in noise (Moller, 2007) and the older adults (Roup et al., 2006). The mean performance of the young adults in noise was 45.60% in the right ear and 41.20% in the left ear. The mean performance of the older adults was 56.80% in the right ear and 43.00% in the left ear.

In order to determine if significant differences existed between the processed data, the noise data from Moller (2007), and the older adult data from Roup et al. (2006), a two-way ANOVA was conducted with *group* as the between subjects factor and *ear* as the within subjects factor. Results revealed a significant main effect of group ($F_{2, 60} = 5.7$; $p < .05$). Post-hoc analysis on the effect of *group* using Tukey's honestly significant difference (HSD) test revealed significant differences ($p < .017$) in recognition performance between the present study and Moller's (2007) young adults in noise, and the present study and the Roup et al. (2006) older adults. The processing in the

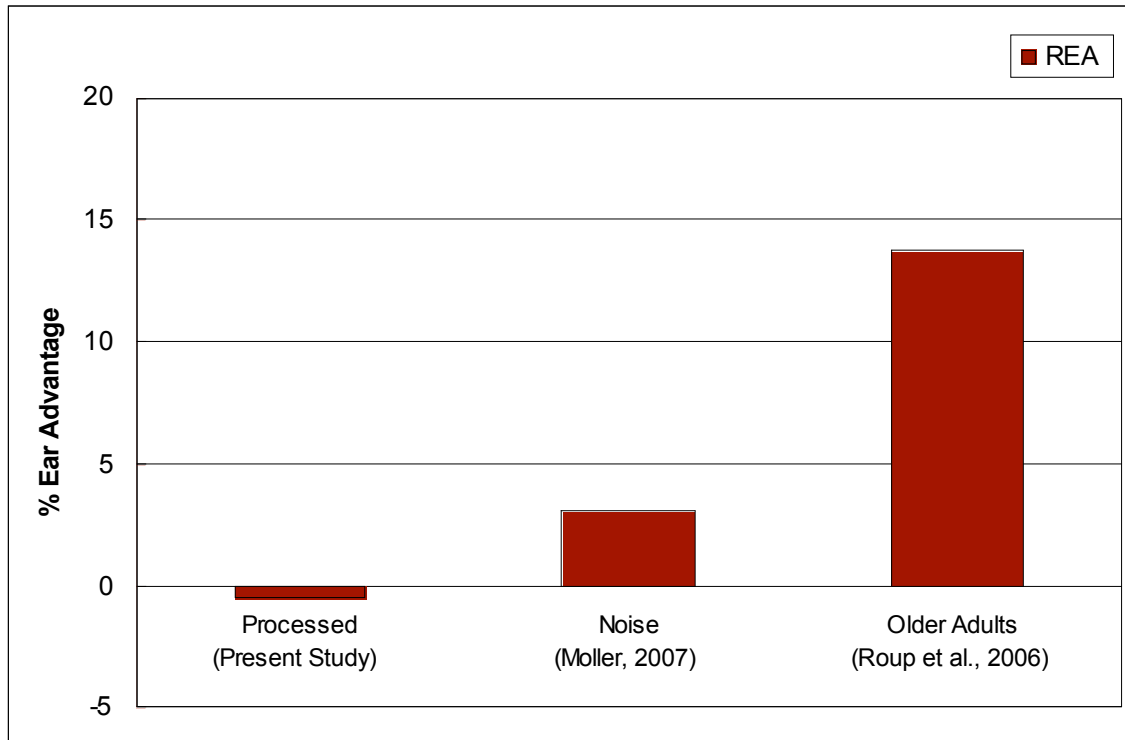


Figure 2. Mean REAs (in percent) for dichotic NU-6 word recognition performance in the free recall response condition for the current study, Moller (2007), and Roup et al., (2006).

	<u>Right Ear</u>	<u>Left Ear</u>	<u>Overall</u>
	%	%	%
<u>Young Adults Unprocessed</u>			
Mean	84.40	77.00	80.70
SD	9.70	9.10	9.40
<u>Young Adults Processed</u>			
Mean	64.70	65.20	64.95
SD	10.70	10.70	10.70
<u>Young Adults Noise</u> (Moller, 2007)			
Mean	45.60	41.20	43.40
SD	9.74	9.48	9.63
<u>Older Adults</u> (Roup et al., 2006)			
Mean	56.80	43.00	49.90
SD	19.30	25.60	23.56

Table 2. Means and standard deviations of dichotic word recognition performance from the free recall response condition for right and left ears, and combined across ears (overall) in both conditions (unprocessed and processed), in noise (Moller, 2007), and older adults (Roup et al., 2006).

present study reduced overall recognition performance relative to the unprocessed condition. However, the reduction did not result in comparable performance levels to that of Moller (2007) and Roup et al. (2006).

Chapter 4

DISCUSSION

The present study examined the performance of young adults with simulated hearing loss in dichotic listening situations. The purpose was to compare the dichotic word recognition of the young adults with simulated hearing loss (processed; Moore & Glasberg, 1993) to that of older adults. Results indicated two main findings. First, there was significant reduction in overall recognition performance from the unprocessed condition to the processed condition. The reduction in performance was consistent across all response conditions (free recall, directed right & directed left). Poorer performance in the processed condition is unsurprising given the increased difficulty of the task. Similar results were reported by Moller (2007). She added speech spectrum noise to the dichotic recognition task and found a significant reduction in overall recognition performance for her group of young adults. Second, small and consistent changes in the magnitude of the ear difference score (i.e., right ear minus left ear) were observed between experimental conditions (unprocessed vs. processed). Based on previous research reducing the dichotic recognition performance of young adults (Moller, 2007), it was expected that the ear difference scores in the processed (i.e., more difficult) condition would increase. As expected, the REA in the directed right condition increased from 7.00% (unprocessed) to 11.20% (processed). The left ear advantage in the directed left condition shifted slightly from 4.20% (unprocessed) to 3.30% (processed). A somewhat unexpected finding occurred for the free recall condition. A significant 7.50% right ear advantage was exhibited in the unprocessed

condition, whereas a non-significant ear advantage (0.5%) was exhibited in the processed condition. One would expect that greater task difficulty would result in an increase in the right ear advantage; however, as can be seen in Figure 3, examination of the individual data shows a number of subjects exhibiting a large left ear advantage. Individuals with a large left ear advantage explain the lack of a group right ear advantage.

In the present study, dichotic word recognition scores in the processed condition were better when compared to young adults in noise (Moller, 2007) and older adults (Roup et al., 2006). This discrepancy is due to the difference in methodology used to reduce performance (noise vs. hearing simulation). The simulated hearing loss from the present study was based on reduced audibility consistent with a presbycusis hearing loss alone. Pilot data with a simulation that included spectral smearing resulted in extremely poor performance (e.g., floor effects). Although performance in the processed condition was not reduced to the same level of the young adults in noise and the older adults, the same conclusions can be drawn from the ear advantage scores. The older adults had a much larger REA than the young adults with simulated hearing loss and the young adults in noise (see Figure 2). This result lends support to the conclusion that the older adults ability to process competing speech stimuli was compromised as evidenced by the larger REAs. Overall performance deficits are likely a result of peripheral hearing loss exhibited by older adults. The larger REAs, however, likely signify a deficit in the ability to process binaural competing speech stimuli.

Knowledge of the auditory pathways and interhemispheric transfer can help to explain the right ear advantage. Information from the right ear travels contralaterally

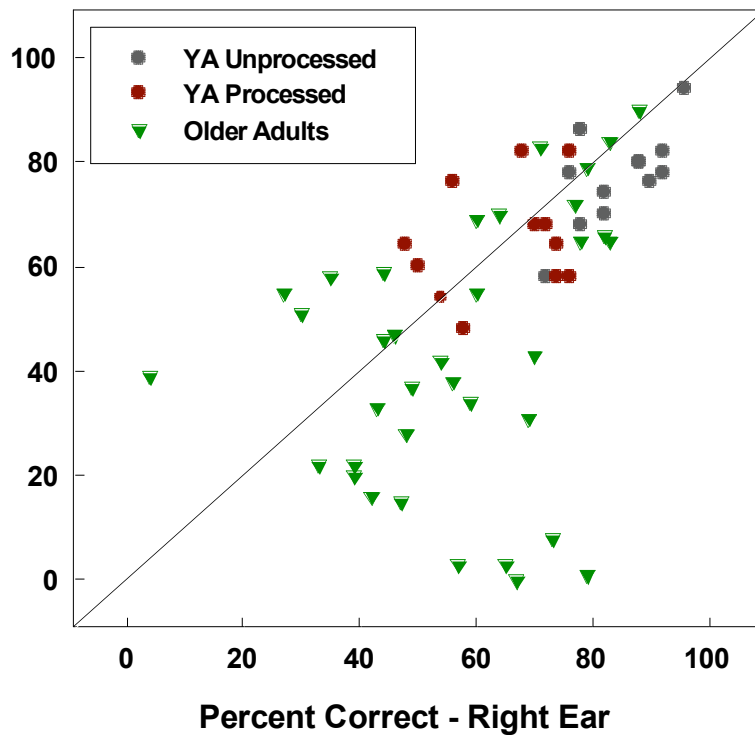


Figure 3. Bivariate plot of individual data for young adults (unprocessed and processed) and older adults (Roup et al., 2006). Equal performance is denoted by the diagonal line, with better performance of the right ear (REA) below the line and better performance of the left ear (LEA) above the line.

directly to the left hemisphere, where language processing typically occurs. The signal in the left ear travels to the right hemisphere and must then be transferred via the corpus callosum to the left hemisphere for processing. The interhemispheric transfer of signals presented to the left ear, which is not necessary for signals presented to the right ear, results in a right ear advantage in dichotic listening conditions.

Research has shown that older adults perform more poorly on dichotic listening tasks, in general, and show greater right ear advantages when compared with younger adults (Bellis & Wilber, 2000; Roup et al., 2006; Strouse & Wilson, 1999). The poorer overall performance in older adults is expected and can easily be explained by the fact that older adults experience peripheral (inner ear) hearing loss as part of the normal aging process. The greater right ear advantage, or left ear disadvantage, is not as easily explained. Some investigators have suggested that the effect found in the elderly may be due in part to an additional loss of energy during interhemispheric transfer that occurs with aging of the central auditory pathways (Jerger, Alford, Lew, Rivera, & Chmiel, 1995). In other words, Jerger and his colleagues suggested that the difference may be due to a central auditory processing deficit, in addition to the peripheral hearing loss that occurs with aging.

Clinical Relevance and Future Research

The results of the present study suggest that the larger REAs exhibited by older adults are due to difficulty dealing with competing binaural stimuli when compared to younger adults with similar levels of recognition performance. This deficit in binaural auditory processing among older adults has implications for aural rehabilitation

strategies. For older adults with sensorineural hearing loss, it is standard practice to fit them with binaural hearing aids. Case study evidence, however, suggests that some older adults with extremely larger REAs perform better when aided monaurally (Carter, Noe, & Wilson, 2001; Chmiel et al., 1997). Tapping into binaural auditory processing deficits through a task like dichotic speech recognition may lead to better clinical outcomes for older adults with hearing loss.

To further develop the results of this study, additional subjects should be tested to gain more knowledge about the dichotic word recognition abilities of young and older adults. A more accurate hearing loss simulation model should be developed. It is important to combine all aspects of sensorineural hearing loss—spectral smearing and a reduction of dynamic range—to reduce the performance of the young adults to the same performance level of the older adults. Comparison of older adults with hearing loss and older adults with normal hearing may contribute to this research, as well. If the older adults with normal hearing exhibit a large right ear advantage, despite their normal hearing, the ear difference can be attributed to an age-related auditory processing deficit, rather than age-related peripheral hearing loss.

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APPENDIX A

Edinburgh Handedness Inventory (Oldfield, 1971)